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I wish my paper to be refereed as research publication	yes
Brief outline of Presentation	• Background Development of a collection/treatment unit.

	Choice of filter media. Project aims • Methods Laboratory columns – construction Dosing and sampling regime Hydraulic conductivity tests • Results and discussion: Influence of filter media on: Hydraulic performance Water quality treatment • Summary and recommendations Summarise findings • Recommend a media and configuration for a unit system.
Biography	Peter has worked at Monash for many years and his research focus has been around stormwater quality monitoring and stormwater treatment systems.

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DEVELOPMENT OF A NEW STORMWATER COLLECTION & TREATMENT UNIT

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Introduction

Water resources in many countries of the world (such as Australia, some parts of the USA, Europe, and Israel, etc) are under great pressure. With climate change looming and populations increasing, many cities face the imminent reality that water use will reach or exceed the limits of sustainability. Recycling and reuse of water is a strategy that is now widely embraced by governments across the globe. The Federal Senate inquiry into Australian's urban water management made a recommendation that harvesting of general stormwater (runoff from roads, car parks and other urban surfaces) must play an important role in solving the water crises in Australian urban areas (Allison et al, 2002).

Urban stormwater is both a resource and a threat to the environment, with some of its key characteristics listed below:

- It is a large untapped source of water, generated close to where it is needed. The amount of stormwater discharged annually in all large cites in Australia is approximately the same, or greater than, the entire annual water demand of these cities (PMSEIC, 2007);
- Runoff from developed catchments is far greater in volume and flow rates than runoff from natural catchments resulting in degradation of creeks and waterways. Stormwater harvesting can protect and enhance the health of urban streams by restoring flows and water quality to pre-developed levels (Fletcher et al, 2007);
- Stormwater harvesting systems can function with very low energy use, since its treatment can be done while it is being collected (using gravity). We can use the urban landscape to actively treat stormwater.

However, currently runoff from paved areas such as roads and car-parks remains a largely untapped resource. This is often due to a lack of harvesting technologies that can fit into space-constrained dense urban environments. Although some attempts have been recently made to collect and use stormwater in Australian cites, very few technological developments have been tested and properly trialled and the field remains relatively unexploited. No simple modular systems for integrated stormwater treatment and harvesting systems exist on the market, with no patents being registered in the field of stormwater treatment.

This paper presents the results of the first stage of a laboratory study that aims at the development of porous pavement filtration systems for safe harvesting of stormwater.

Methodology

The conceptual design of modular porous pavement technology

The system is modular and therefore simple to install into most urban areas. It is a simple treatment train packaged in a box (Figure 1-left), which consists of (Fig. 1-right):

(1) A trafficable porous pavement grate on top that removes gross pollutants and could be used as a part of path, car park or light trafficable road;

(2) A sediment trap underneath that removes sediment, attached pollutants and a fraction of pathogens, and

(3) A filter at the bottom that removes dissolved pollutants, as well as remaining pathogens.

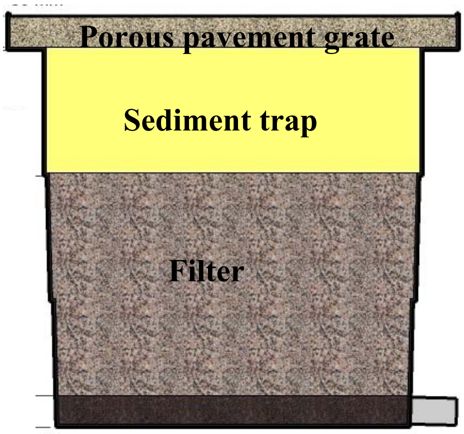

Figure 1: enviss box that treats stormwater (Patent Pending)

The system is to be used to treat stormwater to non-potable water standards. The first objective of its development was to find a filter media that can remove key pollutants dissolved in stormwater.

The filter development

In order to develop a filter that can remove dissolved pollutants such as nitrogen and heavy metals, a control lab study was carried out. Large columns were built mimicking the vertical profile of the modular unit.

The columns were constructed out of 385 mm diameter PVC pipe and consisted of: a porous paver top, a sediment trap, filter media and a drainage layer (Figure 2, please note that the design of the sediment trap and porous pavement top are not presented in this paper since they were results from parallel studies, e.g. Yong, 2008 discusses clogging of various porous pavements).

Two different mixtures of media, referred to here as Media A and Media B, were tested and each media was tested for two different depths (150 mm and 250 mm). Three replicates for each of the four configurations were used to allow for statistical comparisons, and as a result a total of twelve columns were constructed.

Initial hydraulic conductivity rates were obtained for each column from tests using the principles of Darcy's Law. The aim was to determine infiltration rate of the filters at the start of their operational life, (i.e. 'clean filters'). Potable water was applied to each column via a sprinkler and a constant head maintained for the duration of the hydraulic conductivity test. Outflows were measured several times a day for 5 days. Using this flow rate, the depth of filter media and the measured head above the filter, the hydraulic conductivity, k, was calculated.

Columns were then dosed using semi-synthetic stormwater made up in a 1400 litre tank, as used in a number of published studies (e.g. Bratieres et al, 2008); sediment from a stormwater treatment wetland was added, along with nutrients (various species of nitrogen and phosphorus) and heavy metals (copper, lead, zinc, cadmium, manganese, nickel and chromium) so that the concentrations approximate average levels found in stormwater (Duncan, 1999). Diesel was added to provide hydrocarbons, and microorganisms (*Escherichia coli*, *Clostridium perfringens* and fRNA phages) were also added in concentrations commonly found in stormwater.

Figure 2: Columns: In the laboratory (left), and construction details of a column (right).

The tank was continuously mixed while the stormwater was applied to each of the columns. In total, 200 litres was applied to each column. This volume represents the volume that a filter sized to 0.3% of its catchment would receive in an average Melbourne storm. It is calculated by taking the average Melbourne rainfall, (minus 1mm of losses from each rainfall event), times the surface area of the catchment, divided by the average number of events in Melbourne annually.

This runoff was applied twice a week for 4 weeks, with sampling conducted during the first and final week. A third sampling run was conducted on 6 of the 12 columns, 3 months after the dosing had ceased to determine if a prolonged dry period had any effect on treatment performance. It should be noted that in Run 2, phosphorous was mistakenly not added to the inflow and as a result concentrations were quite low.

Each time the columns were dosed with stormwater, an inflow sample was taken. This sample was made up of several subsamples evenly spaced during the dosing period, providing an average of the inflow concentration for that day. During sampling runs, the outflow samples were made up of 5 subsamples from each column providing an average of the outflow concentration for that column. The first sample was taken after 10 litres had passed through the column. After a further 40 litres had passed the second sample was taken. 40 litres passed between each of the remaining samples.

The samples were sent to a NATA accredited laboratory and analysed for:

- Total Suspended Solids (TSS)

- Total Nitrogen (TN)
- Total phosphorus (TP)
- 7 heavy metals (copper, lead, zinc, cadmium, manganese, nickel and chromium)
- 3 Pathogen Indicators: E. coli and Clostridium Perfringens (for 2 sampling runs), and fRNA phages (for 1 sampling run)
- Total Recoverable Hydrocarbons (THC), and
- Polycyclic aromatic hydrocarbons (PAHs).

Results

Hydraulic conductivities of the media were tested before dosing and found to be consistently high, at over 2000mm/hr. Media 1 had slightly higher flow through rates than Media 2. With a designed flow rate of 2000mm/hr, it is estimated that this filter at 0.3% of its catchment size, would treat 87% of the annual flows in a Melbourne climate. With a surface area of the catchment 333 times the surface area of the filter, this technology will have one of the smallest footprints of all Water Sensitive Urban Design stormwater treatment systems developed to date. It must be noted, however, that the systems will clog and therefore, the design of sediment trap is crucial for their operation.

Table 1 shows inflow and outflow concentrations for all 3 runs, while Figures 3-5 summarise the treatment performance of the filters: Figure 3 – shows changes over time including the impact of drying (i.e. Run 3 was after 3 months of drying), Figure 4 – impact of media type, Figure 5 – impact of filter depth.

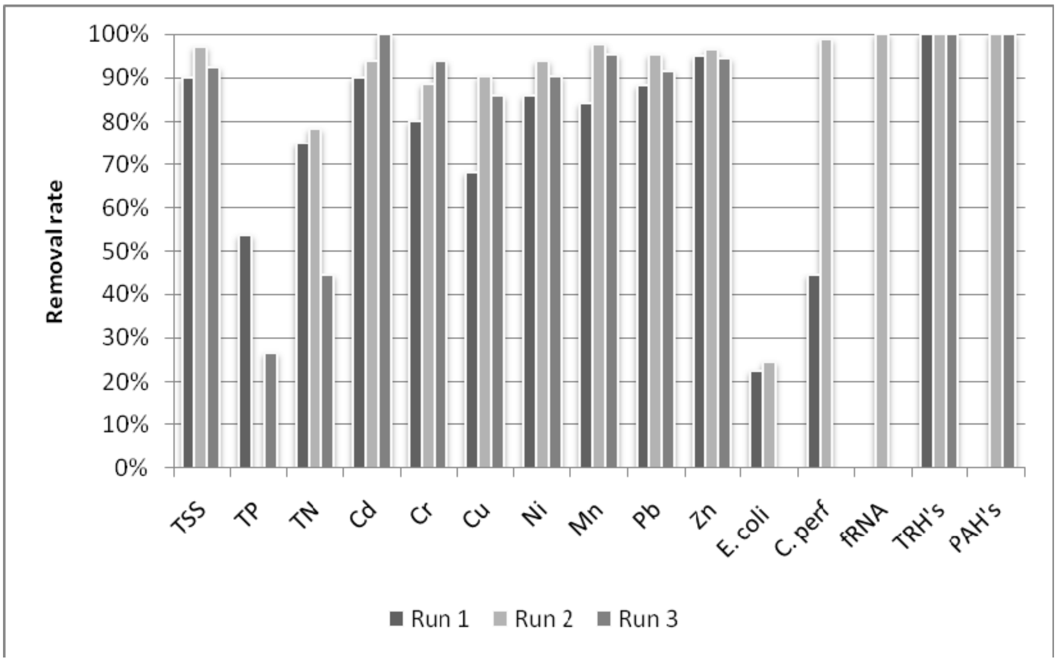

Figure 3: Effect of time and drying - Average removal for all columns for each run

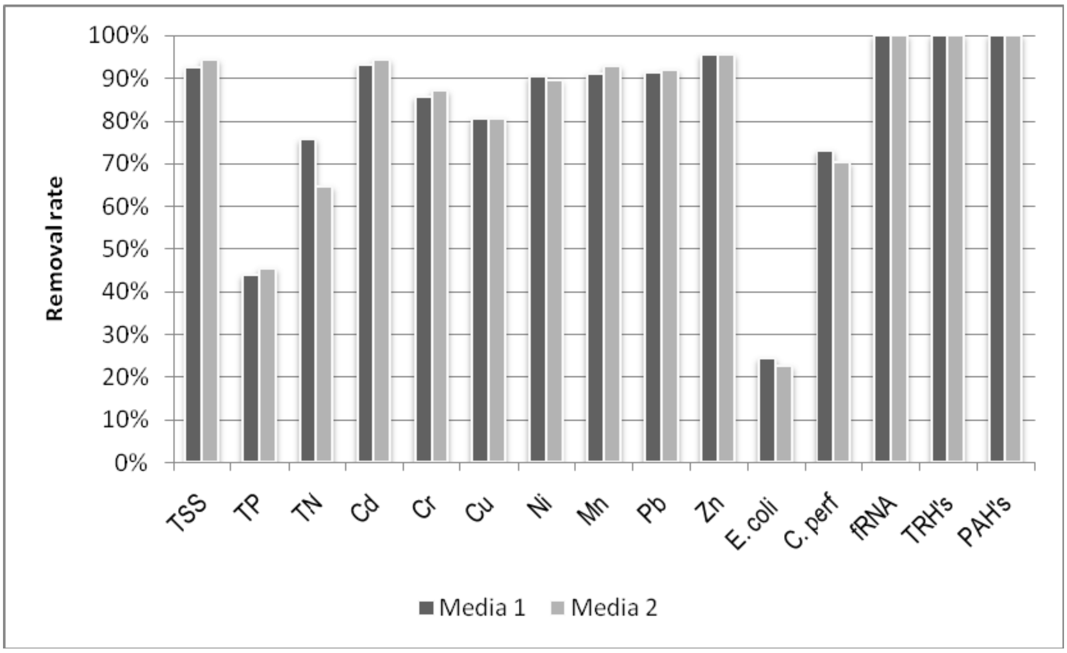

Figure 4: Effect of media type - Average of all columns of each media type.

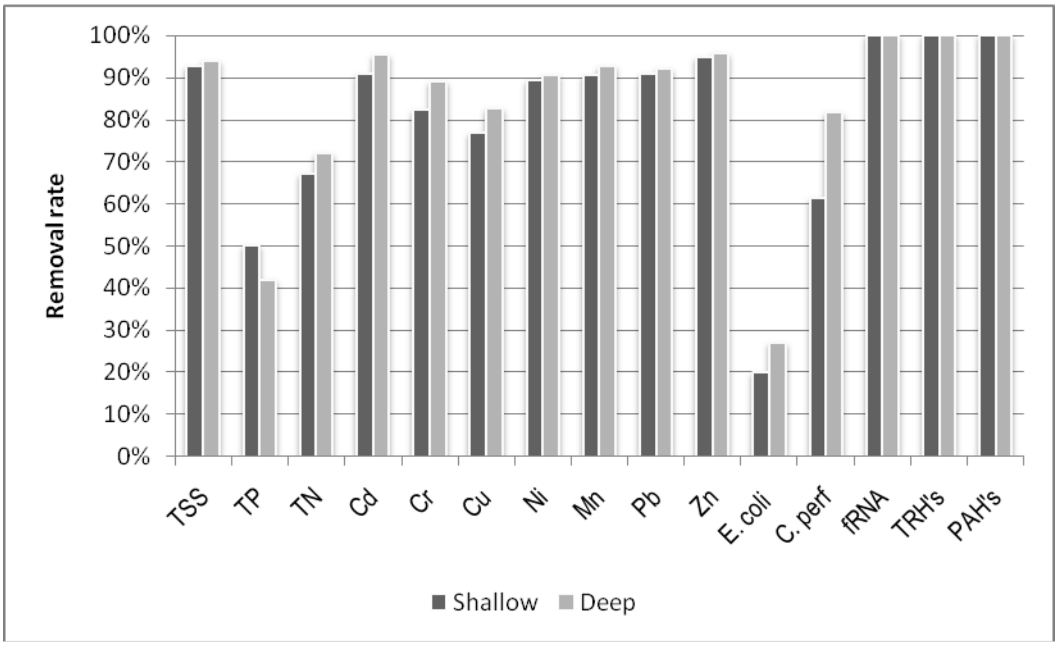

Figure 5: Effect of media depth – Average of all columns of each depth.

Table 1: inflow and outflow concentrations for all 3 runs

	TSS (mg/L)	**pH**	**TP (mg/L)**	**TN (mg/L)**	**Cd (mg/L)**	**Cr (mg/L)**	**Cu (mg/L)**	**Ni (mg/L)**	**Mn (mg/L)**	**Pb (mg/L)**	**Zn (mg/L)**	**E. coli (orgs/ 100mL)**	**C. perfringens (spores) (orgs/100mL)**	**fRNA phages (pfu/100mL)**	**TRH's (mg/L)**	**PAH's (mg/L)**
Run 1 – at the start of filters life																
inflow	*180*	*6.6*	*0.40*	*3.40*	*0.0052*	*0.027*	*0.060*	*0.026*	*0.140*	*0.120*	*0.270*	*96000*	*1700*	*Not added*	*0.47*	<DL
media 1 shallow	24	7.2	0.21	1.13	0.0007	0.0077	0.0220	0.0040	0.0270	0.0163	0.0180	81000	1300	-	<DL	<DL
media 2 shallow	17	7.2	0.19	1.33	0.0005	0.0053	0.0200	0.0040	0.0180	0.0140	0.0140	73000	1300	-	<DL	<DL
media 1 deep	17	7.3	0.17	0.39	0.0005	0.0047	0.0170	0.0030	0.0240	0.0127	0.0110	71000	510	-	<DL	<DL
media 2 deep	15	7.4	0.17	0.59	0.0004	0.0037	0.0180	0.0037	0.0193	0.0117	0.0097	72000	700	-	<DL	<DL
average outflow	18	7.3	0.19	0.86	0.0005	0.0053	0.0193	0.0037	0.0221	0.0137	0.0132	74000	940	-	<DL	<DL
Run 2 – 4 weeks after filters operation																
inflow	*83*	*6.7*	*0.10*	*2.20*	*0.0057*	*0.054*	*0.047*	*0.028*	*0.207*	*0.126*	*0.205*	*58000*	*18000*	*1400*	*12.48*	*0.031*
media 1 shallow	2.7	6.7	0.09	0.51	0.0004	0.0061	0.0052	0.0018	0.0048	0.0066	0.0088	42000	250	<DL	<DL	<DL
media 2 shallow	2.4	6.8	0.10	0.78	0.0003	0.0062	0.0051	0.0018	0.0068	0.0068	0.0076	51000	300	<DL	0.01	<DL
media 1 deep	2.0	7.0	0.10	0.18	0.0003	0.0054	0.0033	0.0016	0.0043	0.0048	0.0056	41000	150	1	<DL	<DL
media 2 deep	2.2	7.0	0.10	0.45	0.0003	0.0063	0.0046	0.0017	0.0043	0.0060	0.0056	42000	170	5	<DL	<DL
average outflow	2.3	6.9	0.10	0.48	0.0003	0.0060	0.0045	0.0017	0.0051	0.0061	0.0069	44000	220	2	<DL	<DL
Run 3 – after 3 months of dry weather																
inflow	*120*	*7.0*	*0.34*	*1.90*	*0.0051*	*0.009*	*0.059*	*0.032*	*0.203*	*0.141*	*0.272*	*Not added*	*Not added*	*Not added*	*13.05*	*0.025*
media 1 deep	10.5	6.9	0.25	0.87	0.0001	0.0005	0.0083	0.0030	0.0107	0.0120	0.0140	-	-	-	<DL	<DL
media 2 deep	7.6	6.8	0.25	1.23	0.0001	0.0005	0.0080	0.0033	0.0087	0.0110	0.0157	-	-	-	<DL	<DL
average outflow	9.1	6.9	0.25	1.05	0.0001	0.0005	0.0082	0.0032	0.0097	0.0115	0.0148	-	-	-	<DL	<DL

The TSS concentrations were reduced by over 90% for all sampling runs. There was no significant difference in performance between design configurations. TSS concentrations improved (to 97%), as the system matured and the small amount of fine material initially resident in the filter media was washed out. After the long dry period however, the TSS removal was slightly reduced (to 92%).

The pH increased slightly for most columns, although was always around neutral. This has important implications for metal removal, as metals are less mobile under neutral to basic pH's (ie. pH's above 7). The average outflow pH of around 7 is well within the recommended range, and should help to retain trapped heavy metals.

The TP concentrations were reduced by between 27 and 58% (the inflow P concentration in run 2 were quite low and therefore not used in the analysis of treatment performance). There was a drop of performance in TP after long dry periods. However both media had similar TP removal rates.

The concentrations of TN were reduced by an average of 75% and 78% in the first and second sampling runs respectively. This reduced to 45% for the sampling run after the prolonged dry period. Media 1 removed more TN than Media 2 while the deep columns performed much better than the shallow columns increasing average removal rates from 67% to 86%.

All of the average ***heavy metals concentrations*** in the first sampling run were reduced by at least 80%, except copper which was reduced by an average of 68%. This increased to above 86% removal for all metals for the next 2 sampling runs. There was no significant difference in removal rates for the different filter media. However, the deep columns again achieved slightly higher removal rates than the shallow columns for all metals.

The E. coli levels were reduced by an average of 23%, while the average concentrations of *C. perfringens* were reduced by 45% for the first run and increased to 99% for the second run (possibly due to clogging). No difference in performance between the two filter media was observed, while deep columns reduced concentrations more than shallow columns. During the first sampling run, the deep columns reduced *E. coli* concentrations by an average of 26% compared to 19%, while for ***C. perfringens*** the difference was more marked, with concentrations in deep columns reduced by an average of 65% compared to 25% for the shallow columns. During the second sampling run, deep columns again performed better, with similar removal rates for the different filter depths for *E. coli*, and significantly lower *C. perfringens* concentrations at the outlet, (although removal rates were quite similar – 98% compared to 99%). ***fRNA phage concentrations*** were reduced by at least 2 orders of magnitude with 10 of the 12 column outflows having fRNA concentrations below the detection limit, (i.e. <2 pfu/100mL).

Total petroleum hydrocarbon (TPH) concentrations were up to 13 mg/L in the inflow, but below the detection limit in the outflow for all columns. Polycyclic aromatic hydrocarbons (PAH's) were also tested and found in concentrations up to 0.031 mg/L in the inflow. This was reduced to below 0.001 mg/L (below detection limit) in all outflows.

Conclusions and further development

Even with this high permeability, all configurations were effective at retaining over 90% of Total Suspended Solids (TSS), over 50% of Total Phosphorous (TP) and over 75% Total Nitrogen (TN) during wet weather spells. These removal rates exceed those stipulated by Melbourne government regulations (i.e. Clause 56.07-4) which states that reductions in TSS, TP and TN concentrations should be over 80%, 45% and 45%, respectively. Even after 3 months of drying, the performance was good with only TP failing the target (further research is needed to improve TP removal).

In terms of reuse, heavy metals, hydrocarbon and microorganisms removal is also very important. All of the average heavy metals concentrations were reduced by at least 80% in the first sampling run (except copper which was reduced by an average of 68%), and increased to over 90% in the second sampling run and 86% in the third sampling run. The two filter media types showed little difference in performance. Total hydrocarbon concentrations and polycyclic aromatic hydrocarbons were below detection in the outflow for all configurations.

However, removal of microorganisms was poorer than expected, with *E. coli* levels being reduced by only 23%. *Clostridium perfringens* concentrations were reduced by just 45% during the first sampling run but increased to 99% for the second run. fRNA phages were only tested in the second sampling run with the filter able to achieve 2 orders of magnitude reduction in concentrations.

This work presents only the first stage of the development of enviss systems (Figure 1). The second stage of the laboratory work is currently underway which aims to solve some identified problems : (1) increase performance of TP to over 60% even after dry weather and prolonged use of filters, and (2) remove pathogens to levels required in Class A. At the same time, a software package for simple sizing of enviss filtration systems is under development. The software also determines the size of the storage for harvested and treated stormwater.

The first generation of technology have been also trialled in the field with two systems already used in practice (see McCarthy et al, 2009 for more details).

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References

Allison (2002) The value of water: Inquiry into Australia’s management of urban water. Report to Senate Environment, Communications, Information Technology and Arts References Committee, Parliament of Australia, Canberra, ACT.

Bratieres, K., Fletcher, T.D., Deletic, A., Zinger, Y., (2008), Nutrient and sediment removal by stormwater biofilters: A large-scale design optimisation study, Water Research, 42 (14), 3930-3940

Fletcher, T.D., Mitchell, V.G., Deletic, A., Ladson, A. (2007). Is Stormwater Harvesting Beneficial to Urban Waterway Flow?, Water Science and Technology 55(4), 265-272

McCarthy, D.T., Deletic, A., Fletcher, T.D., Poelsma, P.J., Lewis, J. (2009) Field Testing of Two Treatment Technologies for Mitigating Risks of Stormwater Reuse. Paper to be presented at this conference

PMSEIC – prime minister’s Science Engineering and Innovation Council Working Group (2007), Water for Our Cities: building resilience in a climate of uncertainty, a report of PMSEIC Working group, June 2007

Yong, C.F., Deletic, A., Fletcher, T.D., Grace, M.R. (2008) The Clogging Behaviour and Treatment Efficiency of a Range of Porous Pavements. Paper presented at the 11th International Conference on Urban Drainage (ICUD), Edinburgh, UK